Disclosure of the Invention and Claims amended by Amendment under Article 34 of PCT, filed on October 12, 2004

DISCLOSURE OF THE INVENTION

A multi-layer laminated circuit board according to the present invention comprises: an in-built multi-layer transformer formed by laminating a primary winding and a secondary winding, a dielectric sheet constituted by a non-magnetic body, and magnetic sheets provided so as to sandwich said dielectric sheet and forming a core via a central through hole formed in said dielectric sheet and a peripheral edge of said dielectric sheet; and a wiring sheet formed with a circuit pattern. In a preferred embodiment, the wiring sheet may be laminated onto an upper surface or a lower surface of the multi-layer transformer, or the multi-layer transformer may be provided on a part of the wiring sheet. The multi-layer laminated circuit board may further comprise a laminated component sheet formed with a laminated component, or a thick film, a passive chip element, and an active chip element may be mounted on a top surface thereof. In this case, either the thick film, or the passive chip element, or the active chip element may be mounted on the top surface. Note that here, the "non-magnetic body" is a substance having a smaller magnetic permeability than at least the magnetic sheet. The "dielectric sheet" is a sheet having a greater resistivity than at least the magnetic sheet, and may be referred to as either a dielectric sheet or an insulating sheet.

In the prior art, the multi-layer transformer is mounted on a printed wiring board as an individual component. However, limits have been reached in reducing the size of the multi-layer transformer package and reducing the amount of wiring between

the multi-layer transformer and other components. Hence, in the present invention the multi-layer transformer is incorporated into the multi-layer laminated circuit board. As a result, the multi-layer laminated circuit board is packaged, and therefore the multi-layer transformer package is omitted. Moreover, wiring can be provided in the lamination direction, leading to a reduction in the surface area occupied by the wiring, and therefore the wiring between the multi-layer transformer and other components can be reduced to a minimum.

The multi-layer transformer that is incorporated into the multi-layer laminated circuit board in a preferred embodiment of the present invention is constituted by the following laminated body. This laminated body comprises: a first magnetic sheet; a first dielectric sheet laminated onto the first magnetic sheet and constituted by a non-magnetic body having a through hole formed in the center thereof; a first winding positioned around the through hole on the first dielectric sheet and constituted by one or both of a primary winding and a secondary winding; a second magnetic sheet laminated onto the first winding so as to contact the first magnetic sheet on a peripheral edge of and through the through hole in the first dielectric sheet; a second dielectric sheet laminated onto the second magnetic sheet and constituted by a non-magnetic body having a through hole formed in the center thereof; a second winding positioned around the through hole on the second dielectric sheet and constituted by the other of, or both of, the primary winding and the secondary winding; and a third magnetic sheet laminated onto the second winding so as to contact the second magnetic sheet on a peripheral edge of and through the through hole in the second dielectric sheet. Further, the multi-layer transformer is preferably formed by laminating

together a plurality of these laminated bodies such that the third magnetic sheet, excluding the third magnetic sheet on an upper end, doubles as the first magnetic sheet of the laminated body thereabove, and through holes respectively connecting the plurality of primary windings to each other and the plurality of secondary windings to each other are preferably provided in the magnetic sheets and dielectric sheets.

The dielectric sheet has the following advantages over a dielectric layer which is formed by coating the winding with a dielectric paste. (1) The dielectric sheet takes a solid form rather than a paste form and therefore has a uniform film thickness regardless of the presence or absence of a winding. As a result, a sufficient film thickness can be secured even in the parts where a winding is present. (2) Since the dielectric sheet is not in paste form, very little matter diffuses from the windings. As a result, the insulating property between the primary windings and between the secondary windings does not deteriorate.

Further, a through hole is preferably formed in the center of the dielectric sheet, and the dielectric sheet is preferably formed to be smaller than the magnetic sheets. Thus, when the dielectric sheet is sandwiched between the pair of magnetic sheets, the magnetic sheets contact each other in the center and on the peripheral edge of the dielectric sheet such that the magnetic sheets form a core. Since the dielectric sheet is interposed between the primary winding and secondary winding, an excellent insulating property can be realized.

The multi-layer transformer incorporated into the multi-layer laminated circuit board in a preferred embodiment of the present invention comprises: a dielectric sheet constituted by a non-magnetic body having a through hole formed

in the center thereof; a first winding positioned on one surface of the dielectric sheet and around the through hole, and constituted by one or both of a primary winding and a secondary winding; a second winding positioned on the other surface of the dielectric sheet and around the through hole, and constituted by the other of, or both of, the primary winding and the secondary winding; and a pair of magnetic sheets sandwiching the dielectric sheet, the first winding, and the second winding, and contacting each other on a peripheral edge of and through the through hole in the dielectric sheet.

The dielectric sheet may be constituted by a single sheet or a plurality of laminated sheets. By disposing the primary winding and secondary winding so as to face each other on either side of the dielectric sheet, a primary winding and a secondary winding may be disposed alternately on one surface of the dielectric sheet, and a primary winding and a secondary winding may be disposed alternately on the other surface of the dielectric sheet. When a plurality of dielectric sheets are provided, a plurality of primary windings and secondary windings may be provided on opposite sides of the dielectric sheets. In this case, through holes connecting the primary windings to each other and connecting the secondary windings to each other may be provided in the dielectric sheets.

In the conventional multi-layer transformer, a magnetic layer is formed between the primary winding and secondary winding, and as a result, the electromagnetic coupling coefficient is reduced by magnetic flux leakage into the magnetic layer. Hence, in the multi-layer transformer of the present invention, a non-magnetic layer (the dielectric sheet) is formed between the primary winding and secondary winding. However, a core is not

formed simply by forming a non-magnetic layer, and therefore a through hole is provided in the center of the dielectric sheet, and the pair of magnetic sheets are caused to contact each other through the through hole and on the peripheral edge of the dielectric sheet, thereby forming a core. Thus, in the multi-layer transformer of the present invention, a non-magnetic layer (the dielectric sheet) is formed between the primary winding and secondary winding, and as a result, magnetic flux leakage can be suppressed. Moreover, in contrast to the conventional multi-layer transformer, there is no need to form a dielectric layer by coating the primary winding and secondary winding with a dielectric paste, and hence the insulating property between the primary windings and between the secondary windings does not deteriorate and the gap between the primary winding and secondary winding does not widen.

In a preferred embodiment, the multi-layer transformer may further comprise a magnetic frame aligned with the peripheral edge of the dielectric sheet and a magnetic core aligned with the through hole, and the pair of magnetic sheets may sandwich the dielectric sheet and contact each other via the magnetic frame and magnetic core. In this case also, the dielectric sheet may be constituted by a single sheet or a plurality of (laminated) sheets. When a plurality of dielectric sheets are provided, a plurality of primary windings and secondary windings are provided on either side of the dielectric sheets. In this case, through holes connecting the primary windings to each other and connecting the secondary windings to each other may be provided in the dielectric sheets.

The dielectric sheet is preferably sandwiched between the first magnetic sheet and second magnetic sheet, and the primary

winding and secondary winding are preferably positioned respectively on either surface of the dielectric sheet. The magnetic frame is aligned with the peripheral edge of the dielectric sheet, and the magnetic core is aligned with the through hole in the center of the dielectric sheet. Thus there is little sagging in the pair of magnetic sheets on the peripheral edge and in the center of the dielectric sheet. As a result, the pair of magnetic sheets do not have to be bent to a great extent, and therefore manufacture is easy. Moreover, a magnetic path having a sufficient sectional area can be secured, leading to an improvement in the magnetic saturation characteristic. This action becomes more striking as the number of laminated dielectric sheets increases.

In particular, by matching the thickness of the magnetic frame (the sum total thereof when a plurality of magnetic frames are provided), the thickness of the magnetic core (the sum total thereof when a plurality of magnetic cores are provided), and the thickness of the dielectric sheet (the sum total thereof when a plurality of dielectric sheets are provided), an extremely even multi-layer transformer is obtained. Thus, when a wiring sheet is laminated onto the multi-layer transformer, warping of the wiring sheet can be suppressed, leading to an improvement in the reliability of the wiring sheet.

In a preferred embodiment, the magnetic frame and magnetic core may be connected to each other via a support portion to form a magnetic sheet. In this case, the magnetic frame and magnetic core can be formed simultaneously, and positioning thereof during lamination can also be performed simultaneously.

The multi-layer transformer incorporated into the multi-layer laminated circuit board in a preferred embodiment

of the present invention comprises: a composite sheet having a magnetic pattern in the center and on the peripheral edge thereof, and a dielectric pattern constituted by a non-magnetic body in parts other than the center and the peripheral edge; a first winding positioned on one surface of the dielectric pattern and around the center, and constituted by one or both of a primary winding and a secondary winding; a second winding positioned on the other surface of the dielectric pattern and around the center, and constituted by the other of, or both of, the primary winding and the secondary winding; and a pair of magnetic sheets sandwiching the composite sheet, the first winding, and the second winding, and contacting each other via the magnetic patterns.

The composite sheet may be constituted by a single sheet or a plurality of laminated sheets. By disposing the primary winding and secondary winding so as to face each other on either side of the dielectric pattern on the composite sheet, a primary winding and a secondary winding may be disposed alternately on one surface of the composite sheet, and a primary winding and a secondary winding may be disposed alternately on the other surface of the composite sheet. When a plurality of composite sheets are provided, a plurality of primary windings and secondary windings may be provided on opposite sides of the composite sheets. In this case, through holes connecting the primary windings to each other and connecting the secondary windings to each other may be provided in the composite sheets.

In the conventional multi-layer transformer, a magnetic layer is formed between the primary winding and secondary winding, and as a result, the electromagnetic coupling coefficient is reduced by magnetic flux leakage into the magnetic layer. Hence, in the multi-layer transformer of the present invention, a

non-magnetic layer (the dielectric pattern) is formed between the primary winding and secondary winding. However, a core is not formed simply by forming a non-magnetic layer, and therefore magnetic patterns are provided in the center and on the peripheral edge of the composite sheet, and the pair of magnetic sheets are caused to contact each other through the magnetic patterns, thereby forming a core. Thus, in the multi-layer transformer of the present invention, a non-magnetic layer (the dielectric pattern) is formed between the primary winding and secondary winding, and as a result magnetic flux leakage can be suppressed. Moreover, in contrast to the conventional multi-layer transformer, there is no need to form a dielectric layer by coating the primary winding and secondary winding with a dielectric paste, and hence the insulating property between the primary windings and between the secondary windings does not deteriorate and the gap between the primary winding and secondary winding does not widen.

In a preferred embodiment, the aforementioned composite sheet may be interposed between the primary winding or secondary winding and the magnetic sheet. This composite sheet acts to enhance the insulating property of the primary winding or secondary winding.

In a preferred embodiment, the film thickness of the magnetic patterns may be equal to the film thickness of the dielectric pattern on the composite sheet. In this case, the film thickness of the composite sheet is constant in all locations, and therefore the pair of magnetic sheets sandwiching the composite sheet are also even. Thus, when a wiring sheet is laminated onto the multi-layer transformer, warping of the wiring sheet can be suppressed, leading to an improvement in the reliability of the wiring sheet.

According to the multi-layer laminated circuit board of the present invention, the multi-layer transformer is in-built, and therefore a multi-layer transformer package can be omitted and the wiring between the multi-layer transformer and other components can be reduced to a minimum. As a result, the advantages of a small, light, thin multi-layer transformer can be maximized, enabling a further decrease in the size of electronic equipment.

According to the multi-layer transformer in the multi-layer laminated circuit board in a preferred embodiment of the present invention, the windings are disposed on the dielectric sheet, and hence the film thickness of the dielectric layer can be secured sufficiently even in the parts where the windings are present. Moreover, the dielectric sheet takes a solid form rather than a paste form, and hence very little matter is diffused from the winding into the dielectric sheet. As a result, the insulating property between the primary windings and between the secondary windings does not deteriorate. Accordingly, a great improvement in the insulating property between the windings can be achieved. Furthermore, the dielectric sheet having a through hole formed in its center is sandwiched between the pair of magnetic sheets such that the magnetic sheets contact each other in the center and on the peripheral edge of the dielectric sheet, and therefore the core constituted by the magnetic sheets has a simple constitution and can be formed by means of a straightforward method.

According to the multi-layer transformer in the multi-layer laminated circuit board in a preferred embodiment of the present invention, the dielectric sheet is provided between the primary winding and secondary winding and a through hole is provided in the center of the dielectric sheet such that the pair of magnetic sheets contact each other through the through hole and on the

peripheral edge of the dielectric sheet, thereby forming a core. As a result, a multi-layer transformer having a non-magnetic layer between the primary winding and secondary winding can be realized, and therefore magnetic flux leakage can be suppressed. Moreover, in contrast to the conventional multi-layer transformer, there is no need to form a dielectric layer by coating the primary winding and secondary winding with a dielectric paste, and hence the insulating property between the primary windings and between the secondary windings does not deteriorate and the gap between the primary winding and secondary winding does not widen. As a result, the electromagnetic coupling coefficient can be increased while maintaining the insulating property between the windings. In addition, the insulating property between the primary winding and the secondary winding is enhanced by the interposition of the dielectric sheet in place of the conventional magnetic sheet.

In addition, according to the multi-layer transformer in the multi-layer laminated circuit board in a preferred embodiment of the present invention, by having the pair of magnetic sheets which sandwich the dielectric sheet contact each other on the peripheral edge of and through the through hole in the dielectric sheet, the magnetic sheets themselves function as a magnetic core and a magnetic frame, and therefore the number of components can be reduced.

According to the multi-layer transformer in the multi-layer laminated circuit board in a preferred embodiment of the present invention, the magnetic frame is aligned with the peripheral edge of the dielectric sheet, the magnetic core is aligned with the through hole in the center of the dielectric sheet, and the magnetic frame and magnetic core are sandwiched between the pair of magnetic sheets. As a result, bending of the magnetic sheets on the

peripheral edge and in the center of the dielectric sheet can be reduced. Hence, there is little or no need to bend the magnetic sheets, and therefore manufacture can be made easier. Moreover, a magnetic path having a sufficient sectional area can be secured, enabling an improvement in the magnetic saturation characteristic.

According to the multi-layer transformer in the multi-layer laminated circuit board in a preferred embodiment of the present invention, the magnetic frame and magnetic core are connected via a support portion to form a magnetic sheet, and hence the magnetic frame and magnetic core can be formed simultaneously, and positioning thereof during lamination can also be performed simultaneously. Thus manufacture can be made easier.

According to the multi-layer transformer in the multi-layer laminated circuit board in a preferred embodiment of the present invention, the dielectric pattern of the composite sheet is formed between the primary winding and secondary winding, the magnetic patterns are formed in the center and on the peripheral edge of the composite sheet, and the pair of magnetic sheets contact each other through the magnetic patterns to form a core. As a result, a multi-layer transformer having a non-magnetic layer between the primary winding and secondary winding can be realized, and magnetic flux leakage can be suppressed. Moreover, in contrast to the conventional multi-layer transformer, there is no need to form a dielectric layer by coating the primary winding and secondary winding with a dielectric paste, and hence the insulating property between the primary windings and between the secondary windings does not deteriorate and the gap between the primary winding and secondary winding does not widen. As a result, the electromagnetic coupling coefficient can be increased while

maintaining the insulating property between the windings. In addition, the insulating property between the primary winding and the secondary winding is enhanced by the interposition of the dielectric pattern in place of the conventional magnetic sheet.

Further, by forming the dielectric pattern and magnetic patterns on a single composite sheet, the number of sheets can be reduced and the lamination method can be simplified in comparison with a case in which a dielectric sheet constituted by a dielectric body alone and a magnetic sheet constituted by a magnetic body alone are laminated to form an identical structure.

In addition, according to the multi-layer transformer in the multi-layer laminated circuit board in a preferred embodiment of the present invention, by interposing an identical sheet to the aforementioned composite sheet between the primary winding or secondary winding and the magnetic sheet, the primary winding or secondary winding can be electrically protected, and hence the insulating property can be enhanced.

According to the multi-layer transformer in the multi-layer laminated circuit board in a preferred embodiment of the present invention, the film thickness of the magnetic patterns and the film thickness of the dielectric pattern are equal, and therefore the film thickness of the composite sheet is constant in all locations. As a result, the pair of magnetic sheets sandwiching the composite sheet can be made even, and hence a circuit pattern or the like can be formed on the magnetic sheets with a high degree of precision.